

INCH-POUND

MIL-T-46035B(MR)

31 January 1989

SUPERSEDING

MIL-T-46035A(MR)

28 October 1966

MILITARY SPECIFICATION

TITANIUM ALLOY: HIGH STRENGTH, WROUGHT
(FOR CRITICAL COMPONENTS)

This specification is approved for use by the Department of the Army and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers high-strength wrought titanium alloys, in annealed or heat-treated shapes, having a critical section thickness of one-quarter to two and one-half inches, for critical components other than armor, such as tubes, chambers, and nozzles (see 6.3.1).

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARDS

MILITARY

MIL-STD-129 - Marking for Shipment and Storage

AMSC N/A

AREA FORG

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, U.S. Army Laboratory Command, Materials Technology Laboratory, ATTN: SLCMT-MEE, Watertown, MA 02172-0001 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-Government publications. The following document forms a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

ASTM

- ASTM B311 - Standard Test Method for Density of Cemented Carbides
- ASTM E8 - Tension Testing of Metallic Materials
- ASTM E21 - Elevated Temperature Tension Tests of Metallic Materials
- ASTM E23 - Notched Bar Impact Testing of Metallic Materials
- ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys
- ASTM E146 - Chemical analysis of Zirconium and Zirconium Alloys.

(Application for copies should be addressed to the ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103-1137.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Chemical composition. Unless otherwise specified in the contract or order (see 6.2) the chemical composition of the titanium alloys shall comply with the range proposed by the supplier. The supplier shall submit a certified analysis of each heat to the procuring activity. The statement of analysis shall include all elements intentionally added as well as the percentage of oxygen, hydrogen, and nitrogen present as impurities, and the percentage of iron and copper present. Three grades with respect to impurities may be specified in the invitation for bids, contract or purchase order as shown in table I.

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TABLE I. - Composition - percent, maximum.

Impurity	grade	C	O ₂	N	H
Extra low	EL 1	0.10	0.10	0.02	0.0125
Low	L 1	0.10	.12	.03	0.0125
Normal	N 1	0.10	.18	.04	0.0125

3.2 Processing controls.

3.2.1 Welding. Components shall not be welded, except on prolongations. All welds shall be so located that they will not affect the finished components or the test metal.

3.2.2 Straightening. The material shall not be straightened or worked after the final heat treatment operation.

3.3 Heat treatment. Heat treatment, (solutionizing, cooling, stress-relieving, and aging) shall be performed uniformly on the material being processed. Unless otherwise specified, (see 6.2) the quenching of tubular components shall be done vertically with the bore unobstructed, so as to permit free passage of the coolant through the bore. Aging shall be performed at a temperature of not less than 500°F, and for a sufficient time to insure uniform response throughout the section.

3.4 Mechanical properties.3.4.1 Tensile properties.

3.4.1.1 Yield strength. The yield strength shall be as specified in the contract, or purchase order, or on the applicable drawings.

3.4.1.1.1 Maximum yield strength. The specified yield strength range may be exceeded providing the percent elongation, percent reduction in area, and V-notch Charpy impact resistance do not fall below values specified in table II for the upper limit of the specified yield strength range.

TABLE II. - Minimum mechanical property requirements.

Yield strength Increments (0.2% offset)	Average elongation	Transverse direction	
		Average reduction in area	V-notch Charpy impact resistance (at -40°F)
<u>psi</u>	<u>percent</u>	<u>percent</u>	<u>ft.-lbs.</u>
120,000-129,999	13	25	13
130,000-139,999	11	23	11
140,000-149,999	10	21	10

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TABLE II. - Minimum mechanical property requirements (continued).

Yield strength Increments (0.2% offset)	Transverse direction		
	Average elongation	Average reduction in area	V-notch Charpy impact resistance (at -400F)
<u>psi</u>	<u>percent</u>	<u>percent</u>	<u>ft.-lbs.</u>
150,000-159,999	10	21	10
160,000-169,999	8	15	8
170,000-179,999	6	13	6
180,000-189,999	6	13	6
190,000-199,999	5	12	5
200,000-210,000	5	12	5

3.4.1.1.2 Elevated temperature properties. For applications requiring elevated temperature properties, the contractor shall demonstrate, by presenting published data or conducting special tests that the proposed alloy will meet a minimum transverse yield strength (0.2 percent offset) requirement of 140,000 p.s.i. at 300 degrees F. In addition, the elongation, reduction in area, and V-notch Charpy impact shall be equal to or greater than the values shown in table II opposite the 170,000-179,999 p.s.i. strength range.

3.4.1.2 Ductility. The reduction in area and elongation requirements shall be as specified in table II for the applicable yield strength range.

3.4.2 Impact resistance. The V-notch Charpy impact resistance shall be as specified in table II for the applicable yield strength range.

3.5 Density. The maximum density of titanium alloy shall be 4.70 grams per cubic centimeter. Certification of the density shall be provided by the contractor.

3.6 Dimensions. Dimensions and dimensional tolerances shall be as specified on the applicable drawing, contract or purchase order, (see 6.2) plus any prolongation (see 6.3.2) which is an integral part of the piece as heat treated.

3.7 Identification marking. Unless otherwise specified, each piece shall be legibly and indelibly marked with the piece number, heat number, or designation, the number of this specification, and the manufacturer's identification (see 6.2).

3.8 Workmanship. The titanium alloys shall be uniform in quality and condition; free from seams, injurious segregations, cracks and other defects which, due to their nature, degree or extent, would detrimentally affect the suitability of the material for the intended use.

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4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.2 Classification of inspection. All examination and testing in this specification is classified as quality conformance inspection and shall be to determine conformance to the requirements of the specification to serve as a basis for acceptance of the material covered by this specification.

4.2.1. Government surveillance. Unless otherwise specified, (see 6.2) the contractor will be subject to periodic, random checking of material ordered under this specification through comparison testing of mechanical properties by both Government and contractor (see 4.4.2.3 and 4.6.1.2.1.2). Not more than ten percent of the lots in the contract or purchase order will be subject to this comparison testing.

4.3 Lot. A lot shall consist of all material from the same heat or melt and of the same condition and size submitted for inspection at one time. Identification of each heat or melt shall be maintained throughout manufacture and inspection.

4.4 Sampling.

4.4.1 For chemical analysis. At least one sample for chemical analysis shall be selected from each heat in accordance with ASTM E120.

4.4.2 For mechanical properties tests.

4.4.2.1 For closed and open die forgings. Except when a sampling plan has been specified in the contract or on the purchase order, (see 6.2) at least one sample for mechanical properties tests shall be taken from one piece out of every group of twenty-six or fraction thereof from the same lot. The samples shall be of full cross-section and of sufficient length to obtain specimens in accordance with 4.6.1.2 (see 6.2j).

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4.4.2.2 For tubing and extruded shapes. Except when a sampling plan has been specified in the contract or on the purchase order, (see 6.2) at least one sample for mechanical properties tests shall be taken from each end of each multiple length of tubing or extruded shape. The samples shall be of full cross-section and of sufficient length to obtain specimens in accordance with 4.6.1.2.

4.4.2.3 For Government surveillance tests. One sample for mechanical properties tests shall be taken from each lot to be tested. Samples shall be of full cross section and of sufficient size to obtain specimens in accordance with 4.6.1.2.1.2.

4.5 Examination.

4.5.1 Visual. All material shall be subject to visual examination for compliance with workmanship requirements (see 3.8).

4.5.2 Preparation for shipment. Examination shall be made to determine compliance with the requirements for preparation for shipment (see section 5).

4.6 Tests.

4.6.1 Test specimens.

4.6.1.1 Hydrogen analysis specimens. Hydrogen analysis specimens shall be taken from a location within the sample corresponding to the finish machined surface. Specimens for this purpose may be taken from mechanical test samples.

4.6.1.2 Tension and impact specimens.

4.6.1.2.1 Location of specimens.

4.6.1.2.1.1 For acceptance testing. Two tensile and two Charpy impact test specimens shall be taken from each sample, selected in accordance with 4.4.2 from the locations indicated on the applicable drawing, except that when no location is shown on the drawing, specimens from tubes shall be taken from material at least one and one half wall thicknesses from the end, or original end of a multiple length, so that the longitudinal center lines of the specimens at mid length (of the specimens) are tangent to a circle located as close to midwall of the critical section as possible; or in the case of a forging, as close to the middle of the critical section as possible. Charpy specimens shall be notched on the side nearest the bore surface.

4.6.1.2.1.1.1 For tubular components. Test specimens shall be taken from the 12, 6, 3 and 9 o'clock positions, consecutively, as may be necessary to obtain sufficient tests. Additional specimens, if required, may be taken from a position diametrically opposite the preceding specimen unless a specimen has previously been taken from that location.

4.6.1.2.1.1.2 For Government surveillance testing. Four tensile and ten Charpy V-notch impact test specimens shall be taken from each sample, selected in accordance with 4.4.2.3 from the locations indicated in 4.6.1.2.1.1. Two of these tensile specimens and five of these Charpy V-notch impact specimens

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shall be tested by the contractor and the remainder shall be tested by a Government testing facility.

4.6.1.2.2 Type of specimens.

4.6.1.2.2.1 Tension test specimens. Tension test specimens shall be machined to the form and dimensions of the largest obtainable round specimen shown in ASTM E8.

4.6.1.2.2.2 Impact test specimens. Charpy V-notch impact specimens shall be machined to the form and dimensions shown in ASTM E23. When a standard-sized impact specimen can not be obtained, the contractor, at the option of the contracting officer, may be required to demonstrate, by special tests prescribed by the contracting officer and agreed to by the contractor, that the material he proposes to furnish is satisfactory insofar as impact resistance is concerned.

4.6.2 Test procedures.

4.6.2.1 Preparation of samples.

4.6.2.2 Tension tests. Tension tests shall be conducted in accordance with ASTM E8. The yield strength shall be determined by the offset method by plotting a stress-strain diagram. The limiting offset shall be 0.10 percent (0.001 inch per inch of gage length). The strain rate shall not exceed 0.005 in./in./min. up to the yield strength at 0.2 percent offset.

4.6.2.2.1 Elevated temperature tensile tests. Tensile tests at elevated temperature shall be conducted in accordance with ASTM E21, except that the test temperature and time at temperature shall be as follows:

Test temperature: 300°F
Time at temperature: 30 minutes
Strain rate: 0.005 in./in./min., Maximum

4.6.2.2.2 Yield strength. If the average yield strength for each sample is above the minimum yield strength requirements of the drawing, the piece will be accepted as having met the yield strength requirements.

4.6.2.2.3 Ductility. The average reduction-in-area and elongation shall be determined for each sample. If each average is equal to, or above the average set out in table II for the upper limit of the required yield strength range, the piece will be accepted as having met the reduction-in-area and elongation requirements.

4.6.2.3 Impact tests. Charpy V-notch impact tests shall be conducted in accordance with ASTM E23. The temperature of the test specimen at the time of fracture shall be $-400^{\circ}\text{F} + 20^{\circ}\text{F}$. The error in the Charpy machine shall not exceed $+ 1$ ft.-lbs. for energy values up to 20 ft.-lbs., or $+ 5$ percent for energy values over 20 ft.-lbs. when the machine is tested using comparison specimens prepared by U. S. Army Materials Technology Laboratory (see 6.4). This comparison shall have been made within one year prior to the time of inspection testings.

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4.6.2.3.1 Impact resistance. If the average value for each sample is equal to or above the value given in table II opposite the upper limit of the required yield strength range, the piece will be accepted as having met the requirements for impact resistance.

4.6.2.4 Density tests. Density tests shall be performed in accordance with ASTM B311.

4.7 Rejection.

4.7.1 Examination. A lot shall be subject to rejection for failure to meet the visual and dimensional requirements when examined in accordance with 4.5.

4.7.2 Tests. Unless otherwise specified (see 6.2) where one or more test specimens fail to meet the requirements of the specification the lot represented by the specimen or specimens shall be subject to rejection.

4.8 Retests. When no sampling plan is provided or approved by the procuring agency (see 6.2) and where there is evidence that indicates that the specimen was not representative of the lot of material, and when the detail specification does not otherwise specify, at least two specimens shall be selected to replace each test specimen which failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

5. PACKAGING

5.1 Preservation and packaging. Preservation and packaging shall be level C as specified (see 6.2).

5.1.1 Level C. Cleaning, drying, preservation and packaging shall be in accordance with the manufacturer's commercial practice.

5.2 Packing. Packing shall be level C as specified (see 6.2).

5.2.1 Level C. Material shall be packed in a manner to ensure carrier acceptance and safe delivery at destination. Containers shall be in accordance with Uniform Freight Classification Rules or National Motor Freight Classification Rules applicable to the mode of transportation.

5.3 Marking. In addition to any special marking required by the contract or order, shipments shall be marked in accordance with the requirements of MIL-STD-129.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This specification covers high strength wrought titanium alloys in annealed or heat-treated shapes for critical components such as tubes, chambers, and nozzles.

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6.2 Acquisition requirements. Acquisition documents must specify the following:

- (a) Title, number, and date of this specification.
- (b) Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2)
- (c) Applicable drawing numbers.
- (d) When other than vertical quenching is permitted (see 3.3).
- (e) Minimum yield strength or yield strength range (see 3.4.1.1).
- (f) Impact requirements, if other than in table II.
- (g) Dimensions of components if different than (see 3.6).
- (h) Special identification marking not covered in 3.7.
- (i) If random checking of material by the government is not needed (see 4.2.1)
- (j) Sampling plans when applicable (see 4.4.2.1 and 4.4.2.2).
- (k) Location of specimens for mechanical properties tests and location of critical section should be shown on applicable drawings (see 4.4.2.1).
- (l) Selection of applicable levels of preservation, packaging, and packing (see section 5).
- (m) When special marking for shipment requirements are necessary (see 5.3).

6.3 Definitions.

6.3.1 Critical section. The critical section is the thickest section of a piece which must meet the mechanical property requirements of table II. The properties shown in table II may not be obtainable in all thicknesses covered by this specification. Proper precautions should be taken, by sufficient investigation or tests, to establish that the materials properties can be attained in the required thickness.

6.3.2 Prolongation. A prolongation for purposes of inspection and tests is defined as an extension beyond the finished component length, where the diameter and mass distribution of the extension are not less than those of the component at a point coincident with the end of the finished component from which it extends.

6.4 Charpy specimen. Charpy specimens used for comparison tests should be obtained from the local DCASR office or, in cases where DCASR does not have responsibility over a particular contract, from the U.S. Army Materials Technology Laboratory, Watertown, MA 02172-0001.

6.5 Subject term (key word) listing.

Critical Components	Tubes, Chambers, and Nozzles
Critical Section Thickness	Wrought Titanium Alloys

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Custodians:
Army - MR

Preparing activity:
Army - MR

Review activities:
Army - MI

Project FORG-A198

User activity:
Army - AR

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